GROUND TESTING RESULTS OF LOOP HEAT PIPE USED TO MAINTAIN THERMAL CONDITIONS OF EQUIPMENT

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Traditional thermal control system of satellites designed by SRP SRC "TsSKB-Progress" is based on application of a gas-liquid system (Foton, Bion satellites). This system with a gaseous medium as the heat carrier was used to maintain thermal conditions of instruments located inside the pressurized compartment, and thermal plates were used to heat instruments located outside the pressurized compartment. In the latter case, certain thermal conditions were maintained through adequate pitch of a coil pipe put inside the plate and the plate thickness, which depended on the density of the heat flux released by the instruments to the thermal plate. However, those thermal plates had a significant weight.

As an alternative for the Resurs-DK satellite, SRP SRC "TsSKB-Progress" jointly with TAIS research-and-production association (NPP TAIS) has designed a thermal plate with built-in heat pipes. The thermal conditions of the instruments located on the thermal plate were maintained through heat removal via a loop heat pipe with a pressure controller. The scheme of the experimental facility is given in Fig. 1; LHP structure is given in Fig. 2.

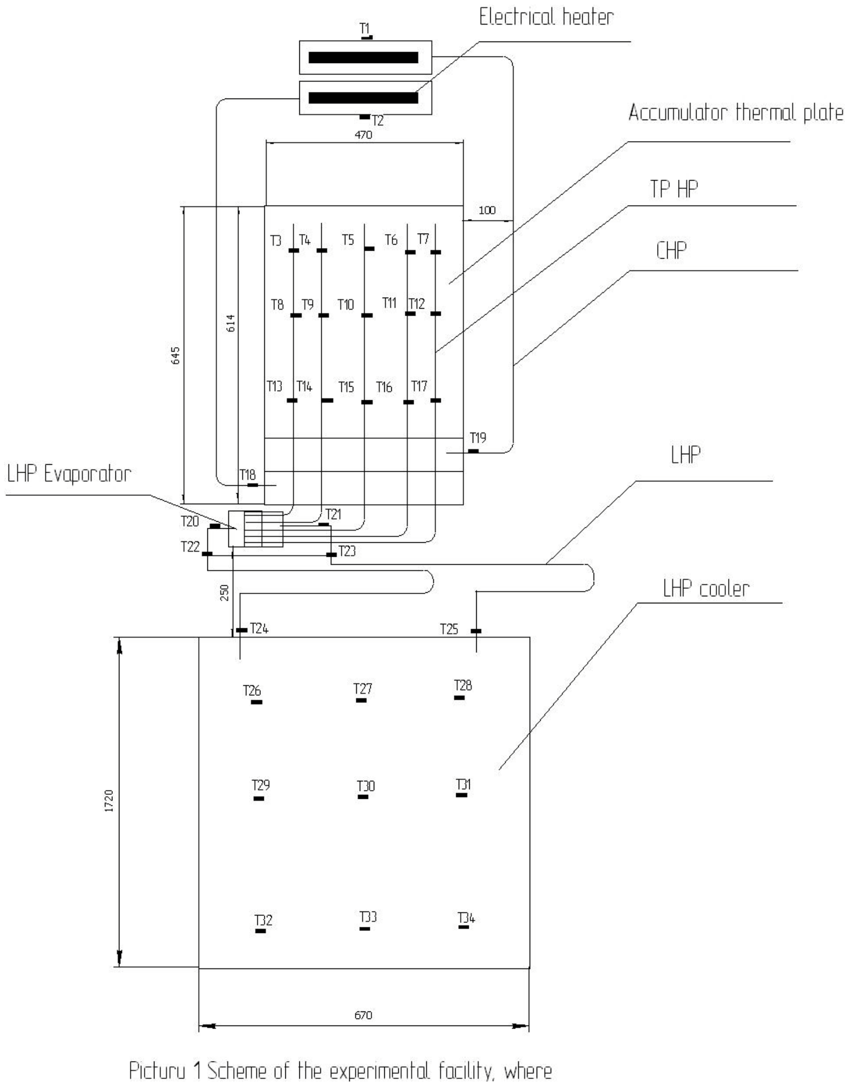

Fig. 1. Scheme of the experimental facility, where LHP – loop heat pipe, TPHP – thermal plate heat pipe, CHP – collector heat pipe

The LHP comprised:

- an evaporator with a contact flange to be attached to the thermal plate. An expansion chamber is attached directly to the evaporator to provide constant feeding of a coolant to the wick and to compensate thermal expansion of ammonia;
- a condenser which is a radiating three-layer honeycomb panel with build-in pipeline and thermoregulating coating of emissivity not less than 0.9 on the outer surface of the plate. The LHP condenser was simultaneously a cooler;
- a 34-W electrical heater installed on the expansion chamber to control active heat removal;
- an automatic coolant flow control valve designed to prevent the thermal plate from chilling below 0 °C. The valve had two positions: start (vapor is directed to the cooler inlet) and bypass (vapor passes through a spare pipeline bypassing the cooler).

NPP TAIS supplied the

thermal plate and loop heat pipe manufactured in conformity with the specifications provided by SRP SRC “TsSKB-Progress”. The tests were performed at the TsSKB-Progress test center.

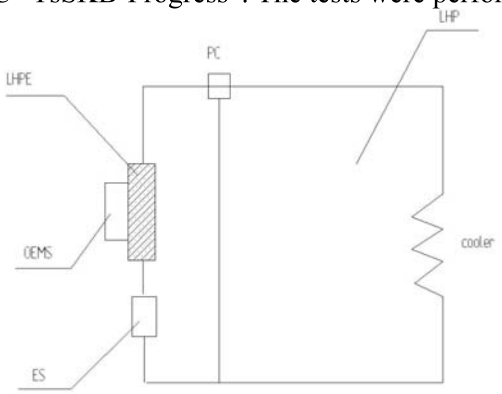

Fig. 2. LHP structure: LHP – loop heat pipe, LHPE – loop heat pipe evaporator, PC – pressure controller, EC – expansion chamber, OEHS – onboard equipment heat simulators

The purpose of the thermal vacuum tests was to prove the efficiency and adequacy of the thermal control means selected, to assess the loop heat pipe response to variation in the external heat load and in the heat load from the instruments.

To meet the challenge the following problems were solved:

- determination of the temperature range maintained on the thermal plate;
- determination of the temperature drop over the thermal plate and LHP structure;
- determination of temperature behavior on swapping the modes of the satellite;
- determination of the pressure control valve response temperature;
- refining of the LHP starting technique and determination of the LHP self-starting conditions;
- refining of the LHP blocking technique by means of the electric heater installed on the expansion chamber.

The test unit was mainly a thermal plate with an instrument heat simulator with output from 0 to 400 W. The LHP with a cooler and a pressure controller was attached to the thermal plate.

Two collector heat pipes were installed to simulate conductive couplings with other structural components. Electric heaters were installed in the evaporation zone of the pipes. The condensers of the collector heat pipes were fixed to the thermal plate. 34 temperature-sensitive elements were installed to control the temperature ranges and drops over the structural elements. The data registration desk received the data from temperature-sensitive elements and automatically processed it.

The thermal plate was manufactured as a three – layer honeycomb panel with five built-in heat pipes.

The test unit was installed in the thermal vacuum chamber (TVC) on a support. Then, together with the support the test unit (except for the cooler) was covered with a multilayer thermal insulation (MLTI). The external heat fluxes to which the test unit was supposed to be exposed to (solar radiation, intrinsic emission of the Earth, reflected fluxes) were simulated with the aid of IR-simulators in conformity with a predetermined timeline corresponding to a real flight of a satellite. Space conditions were maintained by cooling nitric shields of the thermal vacuum chamber down to minus 170 °C and by generation of $1 \cdot 10^{-5}$ Hg mm vacuum.

The automatics of the test unit controlled the instrument heat simulator, IR-simulators, LHP heaters, collector heat pipe heaters.

Around-the-clock tests were run for 3 days.

The tests allowed us to determine the following:

- the surface temperature of the thermal plates varied from minus 7 to +15 °C when external and internal heat loads (the heat flux from the instrument heat simulator) were minimal, and from + 14 to +36 °C when the heat load was maximal; the results met the instrument operating requirements; (the schedules of temperature variation on the thermal plate in the modes of self-starting and expansion chamber heating are given in Figs. 3, 4.);

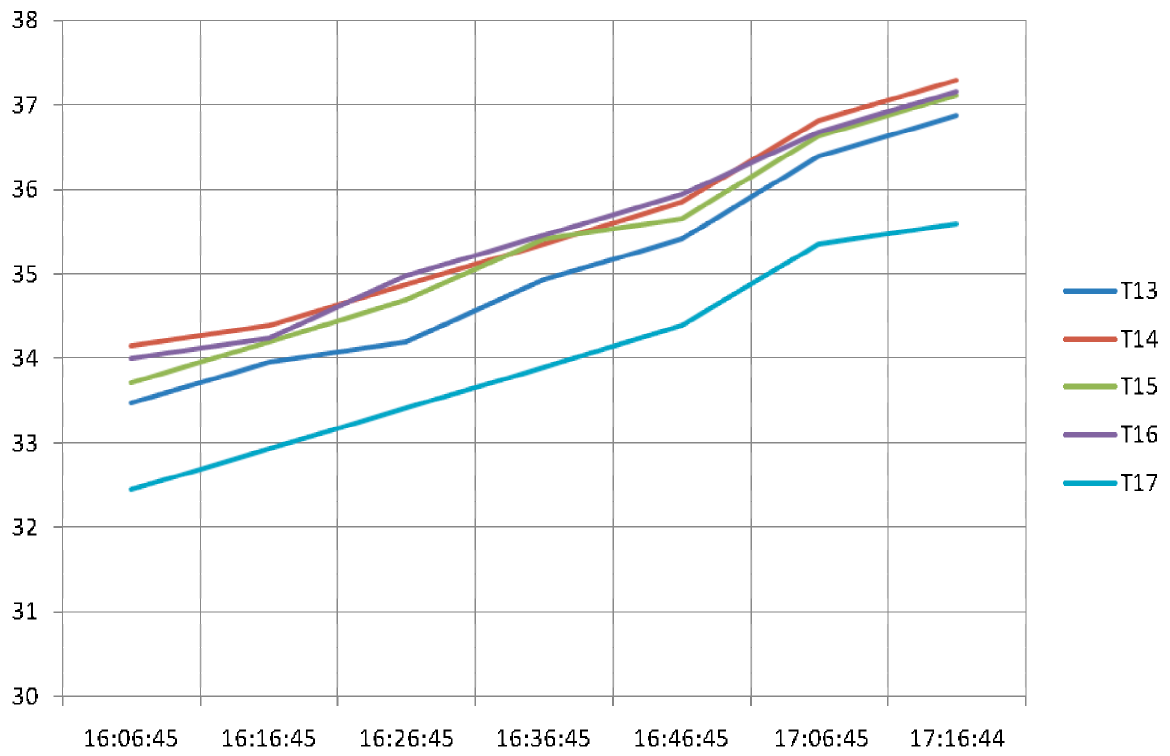

Fig. 3

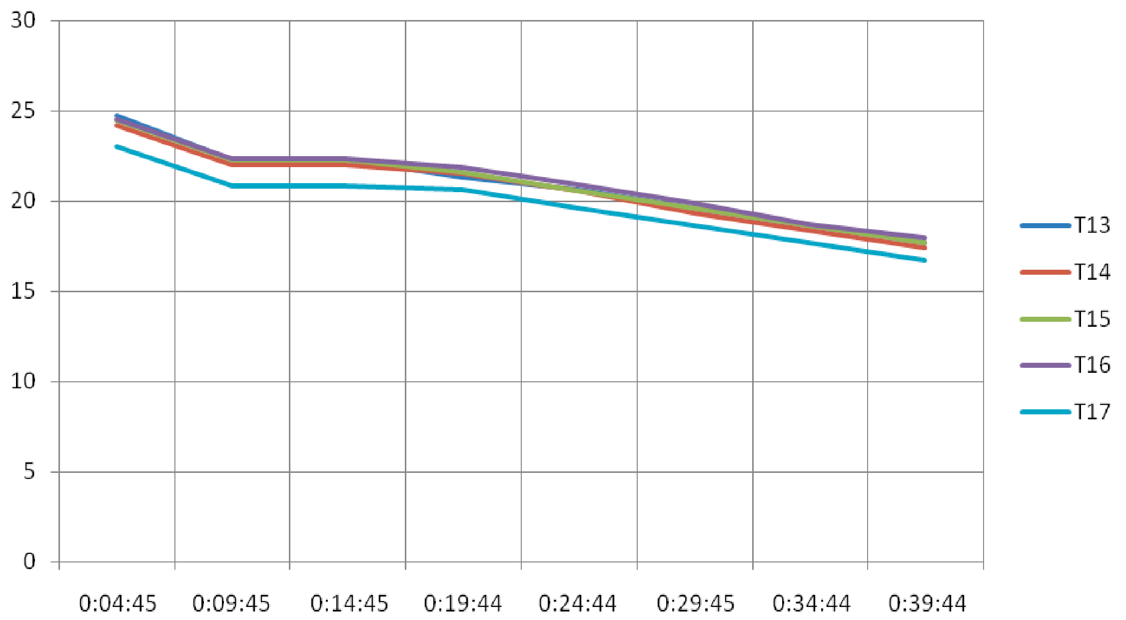

Fig. 4

- the LHP temperature lag varied from 0.01 to 0.13 K/W depending on the mode of operation;
- the temperature drop on the thermal plate was within 2 °C; (the schedules of temperature variation on the thermal plate in the modes of self-starting and expansion chamber heating are given in Figs. 5, 6.)
- the pressure control valve opened at 5 °C, and closed at 0 °C (in one of the operating modes with minimum heat load the valve closed at minus 7 °C);
- the maximal LHP heat effect was Q_{max} = 310 W;

- the 10-W expansion chamber heater allowed to debar LHP from the thermal plate temperature control;
- the LHP self-starting occurred at Q ≥ 80 W heat load of the heat simulator.

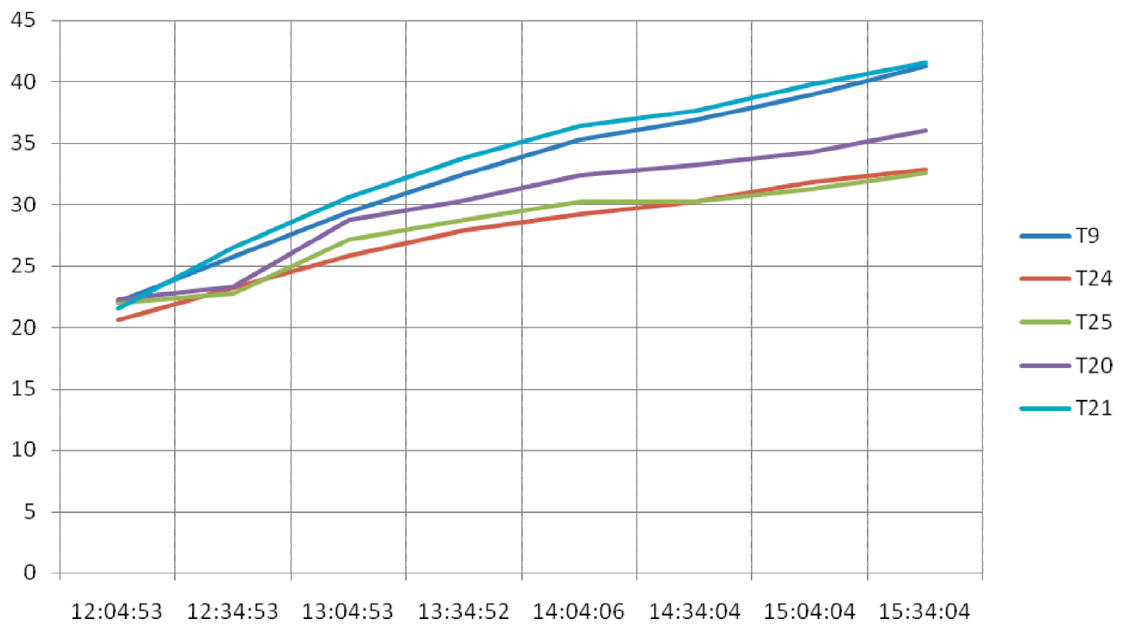

Fig. 5

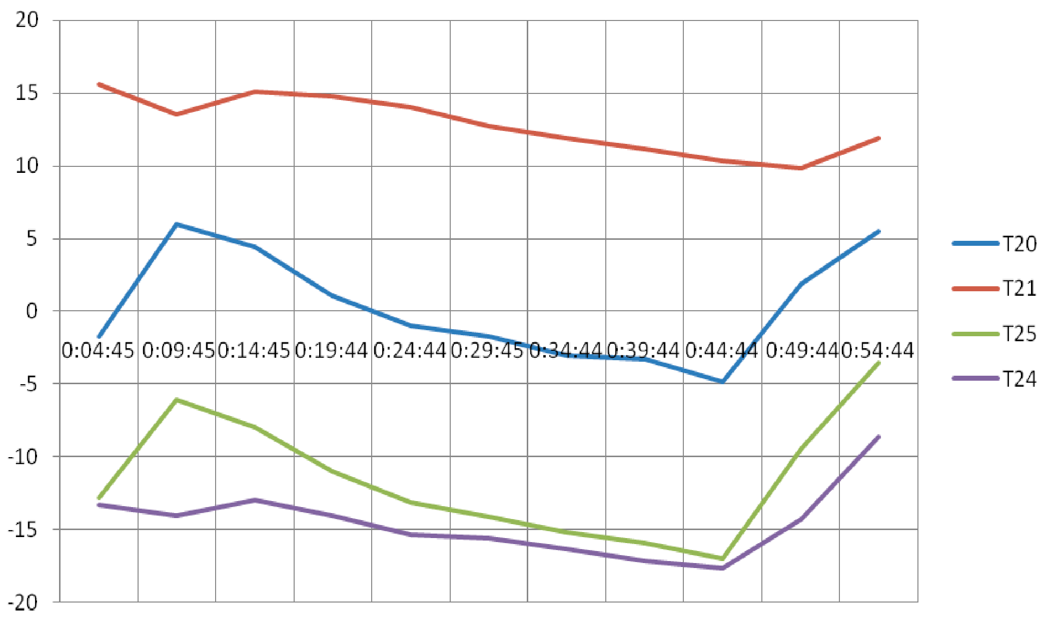

Fig. 6

The following conclusions can be drawn from the test results:

a) Thermal control of instruments located outside the satellite pressurized compartment can be made possible by installing the instruments on a honeycomb panel with built-in heat pipes and providing heat removal to space with the help of a LHP.

b) It is feasible to effectively control operating modes of the thermal control loop.

The following LHP shortcomings were exposed during the tests:

a) The control valve was unable to demonstrate sustained blocking at fixed temperature in all the operating modes of the loop.

b) The loop heat pipe is unable to remove the heat load at Q > 320 W.